RESEARCH

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FINAL REPORT
DELTA P INDEX MEASURING INSTRUMENT

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DELTA P INDEX MEASURING INSTRUMENT

1. INTRODUCTION

This report describes the Delta P Index Measuring Instrument developed by the Ontario Research Foundation for the Devon Coal Laboratories of the Department of Energy, Mines and Resources.

The completed instrument consists of an experimental apparatus (shown in Exhibit 1), a vacuum pump, gas cylinders and regulators, and an Apple 2e microcomputer.

Automatic control of the entire experiment, including data acquisition, is provided by the main computer program "DELTA.P.4", written in the PASCAL programming language to facilitate future developments or changes.

A diagnostic program, "TESTGAS2", was also provided for 'manual' control of the instrument during calibration and/or troubleshooting.

Detailed instructions on the theory and operation of this instrument, as well as complete listings of the "DELTA.P.4" program were supplied in Report No. ES/MI-84-14: "OPERATION MANUAL, DELTA P INDEX MEASURING INSTRUMENT". This information will not be repeated here, and the interested reader is referred to the above mentioned report for operating information. Rather, this report concentrates on describing the problems encountered during final test, the solutions employed and suggestions for further improvements to the instrument and procedures.

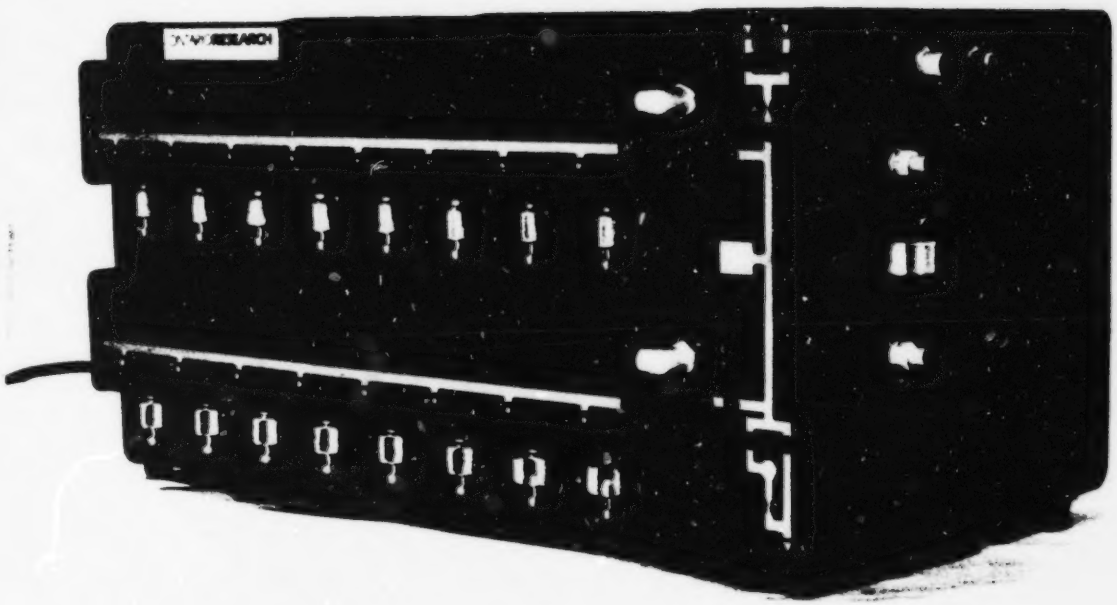

EXHIBIT 1 - DELTA P INDEX MEASURING INSTRUMENT
(EXPERIMENTAL APPARATUS)

2. PROBLEMS ENCOUNTERED AND SOLUTIONS EMPLOYED

2.1 Valve Heating

2.1.1 Problem: It was recognized during the design phase, that the electrical energy dissipated by the solenoid valve coils would cause undesirable heating of the enclosed or adjacent volumes of the manifold and sample cups. This problem was aggravated by the use of normally open cup valves. (This choice was necessary to place the internal volume of the valve on the cup side, in order to meet the manifold volume specification of $19cm^3$.)

This valve selection has the unfortunate side effect of maintaining all the cup valve coils energized during the actual measurement cycle, the duration of which may be several hours.

2.1.2 Solution: The apparatus was substantially redesigned to permit the mounting of all valves on one of several water-cooled aluminium heat-sinks, and a water temperature regulator was supplied to control the cooling water temperature. This substantially reduced the magnitude of the heating effects. The poor thermal conductivity of the stainless steel valve bodies prevented the complete elimination of observable heating effects, however.

2.2 Gas Expansion and Heating

2.2.1 Problem: When the gas in the cups is allowed to expand into the evacuated manifold, a cooling occurs. The gas then absorbs heat from the metal manifold (portions of which may be substantially above room temperature due to heating by the adjacent valves). This causes a gradual pressure rise as the gas warms. This rise, of several mm Hg is of the order of magnitude of the smallest Delta P indices to be measured. This effect is more pronounced with methane, because methane is a better refrigerant at the pressures and temperatures used. Helium does show a similar effect due to the warmer manifold.

2.2.2 Solutions: a) A preheat time, with all valves energized, was added during the saturation periods. This preheat permits the manifold to reach thermal equilibrium so that the effect is the same for each sample cup.

b) A second helium measurement, after 60 seconds was added. It is proposed that this measurement be used to compute the 60 second Delta P index as both the helium and methane will then have had the same length of time to warm to the manifold temperature.

2.3 Continued Adsorption

2.3.1 Problem: The original apparatus had two manifolds so that gas saturation continued at 760 mm Hg until test time. In order to reduce the cost and complexity of the Delta P Index Measuring Instrument, a single manifold design was adopted. (Another reason for this decision was a concern over possible gas transfer during switching of a three-way valve.)

With the single manifold design, the cups are saturated with methane for 90 minutes, then isolated while the manifold is used for the individual measurements. It was discovered that significant adsorption continued even after 90 minutes. Since the cups are isolated during this period, the gas pressure drops due to this adsorption. As a result, the cup is no longer at 760 mm Hg just prior to opening of the valve, and the expanded pressure readings are artificially low as a result.

2.3.2 Solution: Two minute top-up periods were added, just prior to the helium and methane measurements, to ensure that the saturation gas pressures are exactly 760 mm Hg just prior to measurement. The first minute of the top-up period is used to attain pressure control, then the cup valve is opened to perform the actual topping up.

3. SUMMARY

A large number of changes were required during the final test phase of this project. These changes were necessitated by the use of steel (vs. glass) tubing, electrically operated valves, and a single manifold design. As well, several previously unknown subtleties of the existing procedure were uncovered.

Satisfactory solutions to these problems were implemented, primarily by altering the sequence of operation. In this area, the use of the Apple 2e and especially the choice of a high-level computer language (Pascal) were to prove to be very beneficial. No hardware malfunctions of any sort were encountered through the entire development process, and the software proved exceedingly easy to modify. On several occasions, three or more versions of the main program were produced within a day, to permit testing of various hypothetical error sources.

Throughout the instrument has remained reliable and simple to operate. In order to resolve the problems noted above, tradeoffs had to be made. The major effects have been the lengthening of the test cycle, and the requirement for a substantial amount of temperature-controlled cooling water.

4. SUGGESTIONS FOR FUTURE DEVELOPMENT

Based on our current knowledge of the measurement process, it would appear probable that substantial simplification is possible. The existing precision pressure transducer and A/D converter permit pressure measurements to be made about 5 times every second, whereas the manometer used in the original suffered from transient effects, and could not be reliably read until 10 seconds after opening of the valves. It is now possible to trace the entire pressure curve at 0.2 second intervals, right from valve opening. It is probable that this capability could eliminate the need for helium measurements entirely. The existing instrument, with suitably modified software, is an ideal vehicle with which to verify this hypothesis.

Further simplification would be possible if the need for water cooling could be eliminated. One approach would be to devise a mechanically bi-stable 2-way valve, perhaps an electrically operated version of the glass stopcocks of the original apparatus.

The experience gained with this project has yielded a much clearer picture of valve requirements. It might now be possible to approach a valve designer and obtain recommendations on a custom valve and manifold assembly.

If the appropriate valve design could be found, a return to a dual manifold system should be considered, perhaps using mechanical saturation pressure regulation, and a single gas (methane).

Experience with the prototype also suggests that a much smaller vacuum pump could be used and still obtain acceptable pump-down times.

Taken together, these changes could yield a smaller, more portable device with more commercial potential. For laboratory use, the existing instrument is believed totally adequate and we would recommend that it be used in its current state, or with progressive refinements, in order to build up a base of operating experience and to further demonstrate the significance of the Delta P index.

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